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CHAPTER - VI
DESIGN AND CONSTRUCTION OF HOMEMADE COMPUTERIZED
BATTERY CYCLE TESTER

6.1. Introduction

One of the important techniques to study the properties of batteries is to determine and interpret its cycling characteristics. The cycling measurement done manually is tedious and time consuming and hence, it is desirable to introduce automation by the use of computer. Such a computer-based system also minimizes errors that may occur during manual measurements. It can also store the data and display battery characteristics either simultaneously or later as desired by the user. Commercially available battery cycling measurement systems are very expensive. Hence, a home made battery cycle tester unit with data acquisition system was designed, which could be coupled to a PC, a C-V meter and / or an electrometer. In this chapter we present the design of a PC based cycling measurement system, which does not require external electrometer and programmable voltage source.

6.2. General concept of battery

Battery is a device that converts the chemical energy, contained in its active materials, directly into electrical energy by means of electrochemical oxidation – reduction (redox) reactions. The basic electrochemical unit of the battery system is called a galvanic cell [1]. A cell consists of three major parts 1) Anode, 2) Cathode and 3) Electrolyte. The anode gives up the electron
during electrochemical reaction, while the cathode accepts it. The electrolyte is an ionic conductor, which provides the medium for the transfer of ions inside the cell between cathode and anode. The basic electrochemical cell scheme is shown in fig. 6.1. On connecting the external load (L), the electrochemical reaction takes place and the current begins to flow through the load to the cathode. The ions migrate through the electrolyte to complete the cell reaction.

The basic criteria for the selection of anode, cathode and electrolyte are as follows:

6.2.1. Anode:

The anode should have high efficiency as a reducing agent. It should also have very good conductivity, stability and should be fabricated easily.

6.2.2. Cathode:

The cathode must have high efficient oxidizing properties and should be stable, when it is in contact with electrolyte. The cathode should also provide a useful working voltage.

6.2.3. Electrolyte:

The electrolyte must have very high ionic conductivity and should have negligible electronic conductivity to avoid internal short circuit. The electrolyte should be non reactive with the electrode materials. The change of electrolyte properties with temperature must be low.
Fig. 6.1. Schematic representation of basic Electrochemical cell.
6. 3. Battery Parameters

Some of the battery parameters, which are used to scale the performance of the battery systems, are defined here.

6. 3. 1. Open - Circuit Voltage (OCV):

The potential difference between the terminals of cell or battery, when the circuit is open (no-load condition).

6. 3. 2. Current Density:

Current per unit area of the surface of the electrode.

6. 3. 3. Discharge Rate:

The rate, usually expressed in milli amperes, at which electrical current is taken from the cell or battery.

6. 3. 4. Discharge Capacity:

The product of discharge current and the time taken for a particular drop in cell voltage (usually 60% of OCV). It is expressed in milli-ampere-hour (mAh).

6. 3. 5. Energy Density:

The ratio of the energy available from a cell or battery to its volume (expressed in Wh/L) or weight (expressed in Wh/Kg).

6. 4. Charging Methods

6. 4. 1 Constant Voltage

A constant voltage charger is basically a DC power supply, in which its simplest form may consist of a step down transformer from the mains with
a rectifier to provide the DC voltage to charge the battery [2]. The schematic diagram is shown in fig. 6.2

**6. 4. 2 Constant Current**

Constant current[2] chargers maintained the constant current flow by applying the varied voltage to the battery. The schematic diagram of Lm317 based constant current sources is shown in fig. 6.3. [3] This design is usually used for nickel-cadmium and nickel-metal hydride cells or batteries.

**6. 4. 3 Taper Current**

This is charging from a crude unregulated constant voltage source. It is not a controlled charge as in V Taper above. The current diminishes as the cell voltage (back emf) builds up. There is a serious danger of damaging the cells through overcharging. The taper current method is suitable for SLA batteries only. [2]

**6. 4. 4 Pulsed charge**

Pulsed chargers feed the charge current to the battery in pulses [2]. The charging rate (based on the average current) can be precisely controlled by varying the width of the pulses, typically about one second. During the charging process, short rest periods of 20 to 30 milliseconds, between the pulses allow the chemical actions in the battery to stabilize by equalizing the reaction throughout the bulk of the electrode before recommencing the charge. This enables the chemical reaction to keep pace with the rate of electrical energy input. It is also claimed that this method can reduce unwanted chemical reactions at the electrode surface such as gas formation,
Fig 6. 2. The schematic diagram of LM317 based constant voltage method.

\[ V_{\text{out}} = 1.25V(1+\frac{R2}{R1}) + I_{\text{Adj}}R2 \]

Fig. 6. 3. The schematic diagram of LM317 based constant current method.

\[ I_{\text{out}} = \frac{V_{\text{Ref}}}{R1} \]
crystal growth and passivation. If required, it is also possible to sample the open circuit voltage of the battery during the rest period.

6.4. 5. IUI Charging

This is recently developed charging profile used for fast charging [4] standard flooded lead acid batteries from particular manufacturers. It is not suitable for all lead acid batteries. Initially, the battery is charged at a constant current (I) rate until the cell voltage reaches a preset value - normally a voltage near to that at which gassing occurs. This first part of the charging cycle is known as the bulk charge phase. When the preset voltage has been reached, the charger switches into the constant voltage (U) phase and the current drawn by the battery will gradually drop until it reaches another preset level. This second part of the cycle completes the normal charging of the battery at a slowly diminishing rate. Finally, the charger switches again into the constant current mode (I) and the voltage continue to rise up to a new higher preset limit when the charger is switched off. This last phase is used to equalize the charge on the individual cells in the battery to maximize battery life.

6.5. Design and Construction of Homemade Computerized Battery Cycle Tester

Fig.6.4. shows the block diagram of the homemade battery cycle tester measurement system. It is integrated by several parameters such as Power supply, testing unit, programmable gain amplifier, D/A converter, A/D converter, PC interface with software system.
Fig. 6.4. Function diagram for home made computerized battery cycle tester.
6. 5.1. Power supply

The multi stage Voltage regulator power supply unit is shown in fig 6.5. It provides well regulated and stabilized output, which is essential for homemade battery cycle tester. The transformer (Tr1) drops the 230 AC volt mains voltage to 15 volts. The diode bridge (Br1) rectifies, the 15 volts AC from the secondary side of the power transformer and the filter capacitors (C1,C3) helps to maintain a steady input into the regulator. The capacitor (C2,C4) eliminates any high frequency pulses. The unregulated voltage is regulated by the renowned linear positive [5] and negative[6] voltage regulator ICs(LM7805, LM7812 and LM7912) to the required level.

6.5.2 Testing unit

The block diagram of the testing unit or battery charge/discharge unit is shown in fig. 6.6. It mainly consist of op-amp based constant current sources [7], programmable gain amplifier, and battery voltage buffer. Charging is carried out at a constant current till the battery voltage goes to cut off value, when the charging is de-activated. After that, discharge is activated till the battery voltage goes to low cut-off value, then the charging is switch on. The basic circuit of constant current source is shown in fig. 6.7 its function is to stabilize the current through the load. The voltage across the resister R is \( V_{in} \) of inverting input terminal. Therefore

\[
V_{in} = \text{battery current (I}_L\text{)} / R
\]

Battery current \( (I_L) = V_{in} / R \)

The input voltage \( V_{in} \) is converted into an output load current \( I_L \) and the same current flows through the test battery.
Fig 6.5. Circuit diagram of the multi stage Voltage regulator power supply unit
Fig 6.6. Block diagram of testing unit.

Fig 6.7. The basic circuit of constant current in testing unit.

Fig 6.8. Schematic diagram of programmable unity gain amplifier.
The value of the battery resistance does not appear in this equation. Therefore, the output current is independent of the value of the battery resistance.[8]

6.5.3 Programmable unity gain amplifier

The programmable unity gain amplifier circuit is shown in fig. 6.8. It inverts or amplifies without inversion by flipping analog switch. The voltage gain is either +1 or -1, depending on the switch position [8]. The switch is controlled by program. So the charge/discharge positions of the batteries are also change over by program.

6. 5. 4 Control unit

The control unit has two major parts

1) D/A converter
2) A/D converter

6. 5. 4. 1 D/A converter

The Standard 8-bit DAC IC- DAC0800 [9] is employed in the test setup with 2.5V reference. Thus we can provide an output up to 5.00V with a resolution of 20mv. The data bus (pin 5-12) of DAC0800 is connected to port 378H through latch and buffer. The schematic diagram of DAC is shown in fig. 6.9 a.

6. 5. 4. 2 A/D converter

Successive approximation ADC 0804 [10] having 8 bit data output pins (11-18), pin 2,3,5 are control terminals, pin2 is external clock input, and pin 7,8 are analog input terminals. When the start conversion initiates an A/D
Fig 6.9 a and b. Schematic diagrams of D/A converter and A/D converter.
conversion sequence and “EOC - end of conversion” Signal indicates the completion of conversion. An external clock terminal sets the time to complete each conversion. The schematic diagram of ADC is shown in fig 6.9 b.

6. 5. 5 PC- interface

PC can be used for measurement and also the control of external devices and instruments. This method of controlling the external device by connecting it to the PC is known as interfacing. PC interfacing with the outside world calls for extra hardware in the form of plug-in-cards. These cards are costly and difficult to mount inside the PC.

Problem of these types can be overcome by choosing centronics parallel printer port to interface the external devices with the computer. Such a parallel port does exist on laptops also. The parallel printer adapter card can also be used for general-purpose input/output operations. The on board printer/parallel port interface provides an 8-bit digital output register. The centronics parallel printer port pin configuration is shown in table (Appendix (a)). It effectively consists of twelve output lines and five input lines, from the view point of the software, the PC parallel port consist of three hardware port located at three successive addresses. The first port controls the eight data lines (378H). The second port for reading the states (379H) of the cycle tester and third port to send the control signal (37A) to cycle tester. By add-on hardware, one can convert the data and control port of the printer as input port. The acknowledge input line can be used to trigger hardware interrupt in the computer. The pin designation of the status and control port is shown in the Appendix - A. The status port is read only. As mentioned earlier the data controle port can be configured as read/write ports.
Fig 6.9 a and b. Schematic diagrams of D/A converter and A/D converter.
The battery voltage is applying analogue input pin 6 of the ADC0804 via buffer. The start conversion command via pin 16 of parallel port is applied to ADC0804. Since it cannot read 8 bit digital data output from ADC, it is read through the 4-bit status port at a time, we divide the input data byte into two nibbles and read them sequentially. Hence, the ADC data output is multiplexed through two 4-bit section of octal buffers of IC 74LS244 [11] with the help of output-enable signals from pins 2 and 9 of parallel port to output-enable pins 1 and 2 of IC 74LS244, the digital data output from IC 74LS244 is interfaced to the PC via status input port 379H.

6.6. Software

The software is designed as a Windows based user friendly, menu driven package [12, 13] with to carry out the operations in the following sequence.

1. Initialization
2. Set current value to be used
3. Read Cell voltage
4. Set Charge / discharge mode based on preset limits
5. Start charge / discharge operation
6. Increment cycle type and count and record cycle time
7. Provide a real time on screen graphical and textual data display.
8. Repeat from step 4 unless user interrupts
9. If interrupted by user, close down the program gracefully shutting down hardware, disconnects battery terminals and saving all unstored data.
The program starts with the initialization of the hardware configuration, addresses etc., when invoked on the WINDOWS platform. The flowchart representation of software function, D/A converter and A/D converter functions are shown in fig 6.10. a, b and c.

The front panel opens up with the command windows, radio buttons, message windows wherein the user enters user name and sample name. On clicking the Ok button next window appears and prompt the user for settings Window. In the settings window the user can set Time format, Battery parameters and threshold limits of Battery Voltage and currents to be used for charge/discharge cycle. On clicking the Ok button the Main window appears on the screen. The set parameters and the current OCV of the battery can be verified. On clicking the start button, the program starts; graphical and textual information of the process in progress is updated at intervals defined by the user. The Data will be stored in the hard disk at the specified path of the user directory in the spread sheet format for future reference.

6. 7. Result & standardization

The circuit diagram of homemade battery cycle tester is analyzed by using electronic work bench software (EWB5). Then, the required components were spread into broad board level for testing. The tested circuit was converted to printed circuit board (PCB). The single layer PCB was designed by using the protel software and transfer to copper layer, shown in fig 6.11 a, which was made by using the chemical etching technique (Ferric chloride method). The photographic image of the homemade PCB is illustrated in fig 6.11.b. Power supply, testing unit and control unit components were placed in the home made PCB and the output was also tested. Finally,
Fig 6.10 a. Flow chart representation of software function for battery cycle tester.
Fig 6.10. b. Flow chart representation of D/A converter function

Start

Input values from KB

Is it within limits?

NO

Load default value on the data port

YES

Load data on the Data port

Stop
Fig 6.10.c. Flow chart representation of A/D converter function
Fig 6.11 a. PCB layout, designed using Protel software.

Fig 6.11 b. Photographical image of home made printed circuit board.
The constructed circuit board was integrated with the required terminals for external communication and test battery. The DAC output was tested using the various digital input from the data port of the computer parallel port. The output of DAC voltage is feed to testing unit for converting into constant current, which is used to test the battery. The currently available battery terminal voltage is monitored and converted to digital signals by using ADC section.

Fig.6.12. shows the various steps of the designed software. The relevant binary signal of the battery voltage is initially stored in the register and internally converted binary signal to decimal data in the form of battery voltage. The related battery parameter was constructed by using the battery voltage, time and the user defined battery details such as current, active material weight/volume, etc. It is saved in the excel sheet in the respective columns.

The battery cycle tester performance was tested by using maxell CR 2032 lithium battery. The real time of data acquisition from software versus voltage plot of CR 2032 lithium ion cell is shown in fig 6.13. a and b. The generated cell parameters such as current density and power density of CR 2032 lithium ion battery are also plotted from the resulted data are shown in fig 6.13. c and d.
Fig 6.12. Various steps of the designed software for homemade battery cycle tester.
Fig 6.13. a and b. Real time of data acquisition vs voltage of the CR2032 lithium ion cell.

Fig 6.13. c and d. Power density and current density vs voltage of the CR2032 lithium ion cell.
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